IMPACTS OF LAND USE CHANGES ON SOIL PROPERTIES

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Introduction

Changes in land use due to human activities are a widespread problem that usually produce land degradation, and are of considerable concern worldwide in the context of global climate change (Celik, 2005). Over the last century, human activities have been the key drivers of ecosystem transformations through the conversion of natural landscapes into farmlands (Chauchard et al., 2007). The conversion of rangeland into cropland due to agricultural deforestation is a local and global environmental problem (Foley et al., 2005), resulting in changing soil properties and modifying soil physical characteristics that eventually increase soil erosion (Li et al., 2007).

The problems that these practices have created are particularly notable in mountainous areas and in regions with adverse environmental conditions (MacDonald et al., 2000), such as in Mediterranean agroecosystems where natural forest has been progressively cleared and replaced by croplands (Alonso-Sarría et al., 2016). These changes lead to losses of soil nutrients and reduced long-term soil productivity.

Mediterranean mountains are fragile agroecosystems prone to land degradation, due to their climatic conditions characterised by irregular space-time distribution of high intensity rainfall events, followed by long dry periods. There has also been strong anthropogenic pressure during the past centuries. In the twentieth century, following socioeconomic changes, land abandonment notably increased from the mid-1950s onwards, leading to depopulation of rural areas and substantial landscape changes (Navas et al., 2017; Quijano et al., 2016).

Remote sensing enables the comparison of landscape evolution such as the recent land use changes on a multitemporal scale and has the potential to allow calculation of ecological indices.

In this catchment we: i) estimate the variation in the percentage vegetation cover during the successional changes of natural revegetation using remote sensed data; ii) identify the spatial patterns of major soil properties and the differences between land uses.

Study area

The Barués area is an ephemeral stream catchment (23 km^2) of the Arba River located in the central part of the Ebro Basin (NE Spain). From a geological point of view, it lies in the distal part of the Pre-Pyrenean range with characteristically south – southwest low angle strata dipping between 5 - 8 degrees. Rock outcrops in the catchment include two conformable Oligo - Miocene lithostratigraphic units of the Uncastillo Formation, mainly composed of sandstone (Tirapu and Arenas, 1996). The geomorphological setting is clearly conditioned by the low bedding strata, setting up the path of the streams following the strata direction. The climate is continental Mediterranean, characterised by cold winters and hot and dry summers. Rainfall events mainly occur in the spring (April and May) and autumn (September and October) and summer droughts occur between the two humid periods. The area is subject to very intense, though sometimes localised storms. The mean annual temperature is 13.4 °C and the mean annual rainfall is about 500 mm. The soil types in the catchment were classified and mapped in 2014 by Machín (EEAD-CSIC, personal communication) from field surveys, with Calcisols and Cambisols (FAO, 2014) being the most abundant soil types. The soils, developed on Quaternary deposits mainly formed by colluvial and alluvial deposits, are alkaline and have low soil organic carbon contents and secondary accumulation of carbonates.

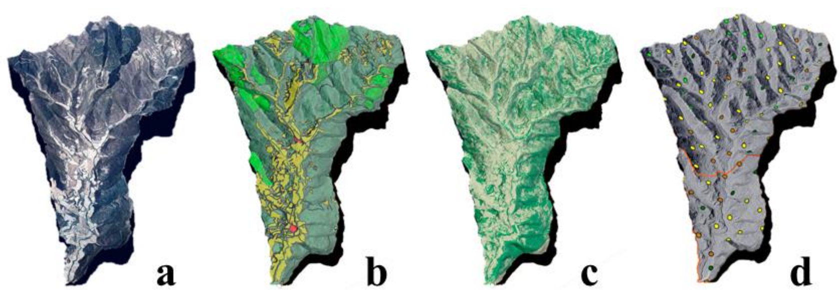

Figure 1. a) Barués catchment. B) 2010 Land use map. C) 1957 Landuse map. D) Sampling points.

Soil sampling and analysis

The sampling sites were distributed proportionally using a previously constructed 500 x 500 m grid created in GIS software that proportionally represents the percentages of the surface occupied by the different land uses in the catchment. The grid location was preserved as much as possible when collecting the samples in representative areas, in order to characterise the properties of the surrounding soil surface within that type of land, while avoiding recently highly disturbed areas. Particle size, soil organic carbon (SOC), TN, pH, $CaCO_3$, electrical conductivity (EC) were analysed in the ≤ 2 mm fraction for the 98 composite soil samples.

The results showed that there were significant differences in all soil properties except for grain size in croplands compared with the other land uses, indicating that land use is one of the main factors affecting the variation in soil properties.

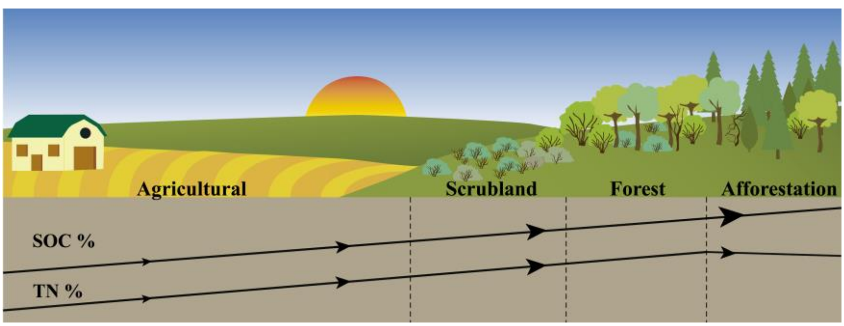

Figure 2. Schematic figure showing how nutrients increase from cropland to natural or afforested land uses.

Remote sensing and soil nutrients

Satellite imagery data were analysed with digital image processing methods and spatial analysis techniques to detect spatial-temporal changes in vegetation and land use. A multitemporal Landsat satellite dataset formed the basis for the change detection procedure. Image series were selected with temporal resolutions ranging from six to twelve years, beginning from the first Landsat image of the study area from 1972 and continuing up to 2017. From the images used to calculate the NDVI, the increase in the value of the index from the 1970s to the present day indicates an increase in vegetation cover and density. For most of the catchment, this was produced by the gradual abandonment of the agricultural land and its progressive transition to natural revegetated cover, in parallel with afforestation.

Conclusions

After land abandonment, the soil physico-chemical properties vary significantly among different land uses in this mountain agroecosystem. The soil properties values indicate that agricultural land has less fertile soils. Due to afforestation and natural revegetation, soil organic carbon and total nitrogen have significantly increased, supporting the key role of management of agricultural lands in soil organic carbon and nitrogen dynamics. The results extracted from remote sensing analysis and soil nutrient quantification suggest that in the short term, afforestation produces a faster increase in soil organic carbon than natural cover, although an increase is not observed in nitrogen.

The results of this research could help policymakers to develop plans to reduce the loss of nutrients and to make decisions about best practices after land abandonment and future afforestation programmes.

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Conferencias y Seminarios del Doctorado en Geología

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